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I HEREBY CERTIFY that annexed hereto is a true copy of documents filed in connection with the following patent application:

Application No.	S2002/0710
Date of Filing	2 September 2002
Applicant	INTUNE TECHNOLOGIES LIMITED, an Irish Company of 9c Beckett Way, Park West Business Park, Nangor Road, Dublin 12, Ireland.

Dated this 4 day of September 2003.

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Clare O' Reilly

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Form No.1

REQUEST FOR THE GRANT OF A PATENT

Patents Act, 1992

The Applicant(s) named herein hereby request(s)

the grant of a patent under Part II of the Act

☒ the grant of a short term patent under Part III of the Act on the basis of the information furnished hereunder

1. Applicant(s)

Name: **INTUNE TECHNOLOGIES LIMITED**

Address: **9c Beckett Way, Park West Business Park, Nangor Road, Dublin 12, Ireland**

Description/Nationality : **an Irish Company**

2. Title of Invention:

METHOD FOR DETECTION OF REGIONS OF INSTABILITY IN TUNABLE LASERS

3. Declaration of Priority on basis of previously filed application(s) for same invention (Sections 25 & 26)

Previous Filing Date	Country in or for which filed	Filing No.

4. Identification of Inventor(s):

Name(s) of person(s) believed by applicants to be the inventor(s) address:

5. Statement of right to be granted a patent (Section 17(2) (b))

Date of assignment from inventors:

6. Items accompanying this Request - tick as appropriate

(i) ☒ prescribed filing fee

(ii) ☒ specification containing a description and claims
specification containing a description only
☒ Drawings to be referred to in description or claims

(iii) An abstract

(iv) Copy of previous application(s) whose priority is claimed

(v) Translation of previous application whose priority is claimed

(vi) ☒ Authorisation of Agent (this may be given at 8 below if this request is signed by the applicant(s))

7. Divisional Application(s)

The following is applicable to the present application which is made under Section 24 -

Earlier Application No:
Filing Date:

8. Agent

The following is authorised to act as agent in all proceedings connected with the obtaining of a patent to which this request relates and in relation to any patent granted -

Name	Address
TOMKINS & CO.	**5 Dartmouth Road, Dublin 6.**

9. Address for Service (if different from that at 8)

TOMKINS & CO., at their address as recorded for the time being in the Register of Patent Agents.

Signed Name(s):
by:
Capacity (if the applicant is a body corporate):

Date: **2 September 2002**

AUTO3113

Title

Method for detection of regions of instability in tunable lasers

Field of the Invention

This invention relates to tunable lasers and the requirement to locate operating points of the tunable laser so that the output of the laser can be switched between different wavelengths. This invention specifically relates to a method to detect hysteresis/unstable regions of laser. Hysteresis in the output of a laser means that the output wavelength and or power of a laser in these regions is related to the previous operating point of the laser and so these regions should be avoided when selected operating points of the laser.

Background to the Invention

Multi section laser diodes are well known in the art and can be switched between different wavelengths. Typically the diode is calibrated at manufacture to determine the correct control currents that should be applied to the laser so as to effect the desired output frequencies from the laser.

One of the first known multi-section laser diodes is a three-section tuneable distributed Bragg reflector (DBR) laser. Other types of multi-section diode lasers are the sampled grating DBR (SG-DBR), the superstructure sampled DBR (SSG-DBR) and the grating assisted coupler with rear sampled or superstructure grating reflector (GCSR). A review of such lasers is given in *Jens Buus, Markus Christian Amann, "Tuneable Laser Diodes" Artect House,*

1998 and "Widely Tuneable Semiconductor Lasers" ECOC'00. Beck Mason.

Figure 1 is a schematic drawing of a DBR 10. The laser comprises of a Bragg reflector sections 2 with a gain or active section 6 and phase section 4. An anti-reflection coating 9 is sometimes provided on the front and/or rear facets of the chip to avoid facet modes. The Bragg reflector takes the form of Bragg gratings 5. The pitch of the gratings of the Bragg reflector varies slightly to provide a Bragg mode with moves in frequency through varying the current supplied to these sections. The optical path length of the cavity can also be tuned with the phase section, for example by refractive index changes induced by varying the carrier density in this section. A more detailed description of the DBR and other tuneable multi-section diode lasers can be found elsewhere *Jens Buus, Markus Christian Amann, "Tuneable Laser Diodes" Artect House, 1998.*

As detailed above such tunable semiconductor lasers contain sections where current is injected to control the output frequency, mode purity and power characteristics of the device. Various applications in telecommunications/sensor fields require that the laser can operate at points in a predetermined frequency/wavelength grid. Moreover many applications require the power output of the device to be within a defined tolerance for each operating point, and in general, the operating points must be distanced from mode jumps and have high side-mode suppression. In order to provide lasers for such applications, each individual device must be characterised to the desired specification, so there is a corresponding need for a

system or algorithm to map the output of the laser over a range of operating currents. For characterisation of lasers in production environments, such a system must also be fast, reliable and automated.

Certain types of tunable lasers present a characteristic that in certain conditions the output wavelength and power of the laser is dependent on the previous state of the laser. If an operating point of the laser is selected where the laser has this characteristic, the output of the laser will be indeterminate and cannot be guaranteed, as it will be dependent on the previous operating point of the laser.

There is therefore a requirement to provide a means to identify such regions.

Object of the invention

The object of the present invention is to provide a method for locating hysteresis regions of a multi-section tunable laser in a fast and efficient manner.

Summary of the Invention

Accordingly the present invention provides a method adapted to identify hysteresis regions of tunable laser so as to enable characterisation of the device to avoid these regions. By identification of the hysteresis regions the operating points of the laser picked by a calibration will not exhibit this effect and are independent of the previous state of the laser.

Accordingly the present invention provides a method for detecting hysteresis in a multi-section tunable laser

diode. The methodology and technique is generic and can be applied to several different types of tunable laser such as DBR, SG-DBR, GCSR etc..

In the preferred embodiment a method of obtaining the hysteresis regions of a laser is provided comprising the steps of

obtaining a first set of measurement values for the output of the laser diode by increasing a first control current through a range of values in a positive direction,

increasing a second control current by a step,

obtaining a second set of measurement values for the output of the laser diode by decreasing the first control current through a range of values in a negative direction,

Increasing a second control current by a step,

Repeating the above steps until a sufficient range of the second control current has been used, and

Identifying in the resultant data set regions of hysteresis.

The identification of regions of hysteresis is desirably effected by:

applying to the resultant data a laplacian or similar operator,

thresholding the resultant data to obtain the hysteresis regions, the hysteresis regions being those regions where the value at a specified current is above the threshold value.

Alternatively the regions of hysteresis may be determined by using an erosion operator to obtain the hysteresis regions of the laser diode.

These and other features of the present invention will better understood with reference to the following drawings.

Brief Description of the drawings

Figure 1 shows a schematic of a Distributed Bragg Reflector Laser diode

Figure 2 shows how measurement plane is obtained

Figure 3 is an example of a measurement where the hysteresis is interleaved

Figure 4 is an example of the hysteresis regions of a DBR laser diode.

Figure 5 shows an alternative method to obtain a measurement plane to Figure 2.

Detailed Description of the Drawings

The invention will now be described with reference to exemplary embodiments thereof and it will be appreciated that it is not intended to limit the application or methodology to any specific example. The techniques used by the method of the present invention are specifically provided to enable the formation of a hysteresis plane which will be understood to have either a value of 1 or 0. As shown in Figure 4 where the value is 1, hysteresis exists in the laser and where the value is 0, hysteresis does not exist in the laser. Using the technique of the present invention it is possible to obtain the required measurement plane shown in Figure 2, in a fast and efficient manner.

It will also be appreciated that as no large changes in current are required while making the measurement, the

total current in the laser does not change as quickly as in techniques a measurement where the first control current is changed back to zero when the second control current is incremented and all the measurements are performed while the first control current is increasing. As the electrical power entering the laser ends up as heat in the laser (for the passive sections) large changes in current will change the laser temperature. As the output characteristics of the laser are temperature dependent it is advantageous to keep the laser temperature constant while performing the measurements. The technique according to the present invention keep the laser temperature more stable as no large changes in current are required between measurements.

Another scheme which is shown in figure 5 illustrate an alternative method of measurement to that shown in Figure 2 where the total current in the laser is kept as constant as possible.

The methodology of the present invention will now be described with reference to a three section DBR device, and it will be appreciated from the person skilled in the art that this is exemplary of the type of device that may be used with the method of the present invention.

Firstly a method to obtain a power plane from the device in a specific manner that allows detection of hysteresis is effected. A subsequent processing of this information may be utilised to convert this data into a hysteresis plane.

A series of power measurements are performed while the laser control currents are varied in a specific way. A

power plane is obtained where the two axes are two of the control currents of the laser. Figure 2 shows how the currents should be varied as described below.

Firstly, a first set of measurement values for the output of the laser diode is obtained by increasing the first current through a range of values in a positive direction. After incrementing a second control current by a step, it is possible to obtain a second set of measurement values for the output of the laser diode by decreasing the first control current through a range of values in a negative direction. These steps may be repeated until a sufficient range of the second control current has been used.

By measuring the plane in this way it is possible to determine where the first control current exhibits the main influence of hysteresis. A plane may be obtained where the output power of the laser is different depending on the previous current in the laser. As can be seen from Figure 3 the variations in output due to hysteresis are interleaved. This is because the first control current is increasing, then decreasing etc..

There is some processing of this data required to obtain a Hysteresis plane. This involves passing an operator to detect the hysteresis. Examples of suitable operators are a Laplacian

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix} \text{ or } \begin{bmatrix} 1 & -2 & 1 \end{bmatrix}$$

or any second order differential operator or any operator which does a similar operation.

This, it will be appreciated, has the effect of producing a large value where hysteresis exists and a small value where hysteresis does not exist. This means that in the result a simple threshold value can be used to detect the hysteresis i.e. where the value is greater than the threshold hysteresis exists and where the value is less than the threshold hysteresis does not exist. Figure 4 shows an example of this.

In some cases cavity mode jumps or other effects can cause discontinuities in the laser, which are also detected by the above method. This is advantageous as detection of these is required for calibration of the device in any case. If this is not required a simple combination erosion and dilation operations removes these effects and the hysteresis region is all that will remain.

It will be appreciated that the present invention provides an efficient manner to effectively determine regions of instability in a laser diode. Although it has been described with reference to an exemplary embodiment, it will be appreciated that it is not intended to limit the present specification in any manner except as may be necessary in the light of the appended claims.

Claims

1. A method of obtaining a measurement plane from a multi-section tunable laser diode is provided comprising the steps of

obtaining a first set of measurement values for the output of the laser diode by increasing a first current through a range of values in a positive direction,

increasing a second control current by a step,

obtaining a second set of measurement values for the output of the laser diode by decreasing the first control current through a range of values in a negative direction,

increasing a second control current by a step,

repeating the above steps until a sufficient range of the second control current has been used, and,

identifying in the resultant data set regions of hysteresis.

2. The method as claimed in claim 1 wherein the identification of regions of hysteresis is effected by:

applying to the resultant data a laplacian or similar operator, and

thresholding the resultant data to obtain the hysteresis regions, the hysteresis regions being those regions where the value at a specified current is above the threshold value.

3. The method as claimed in claim 1 wherein the regions of hysteresis are determined by using an erosion operator to obtain the hysteresis regions of the laser diode.

4. The method as claimed in any preceding claim wherein the value of the increment of the first and second control currents is such that there are no large changes in any single control current between measurements thereby minimising the temperature effect contribution to the output of the laser

5. A method of obtaining a measurement plane from a multi-section tunable laser is provided comprising the steps of:

obtaining a first set of measurement values for the output of the laser diode by increasing a first control current through a range of values in a positive direction and decreasing a second control current in a negative direction at the same time,

increasing one of the first or second control current by a step,

obtaining a second set of measurement values for the output of the laser diode by increasing the second control current through a range of values in a positive direction and decreasing a first control current in a negative direction at the same time, .

repeating the above steps until a sufficient range of the first and the second control current has been used, where the total control currents to the laser are changing at a continuous rate.

6. A method of detecting regions of instability in tunable laser diodes substantially as herein described with reference to and/or as illustrated in the accompanying drawings.

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Drawings

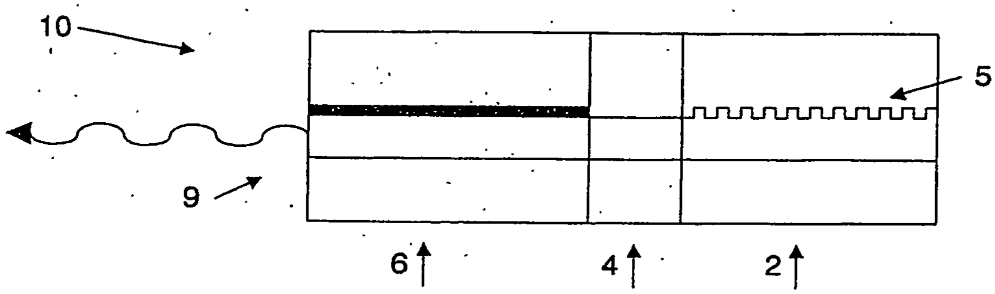

Figure 1

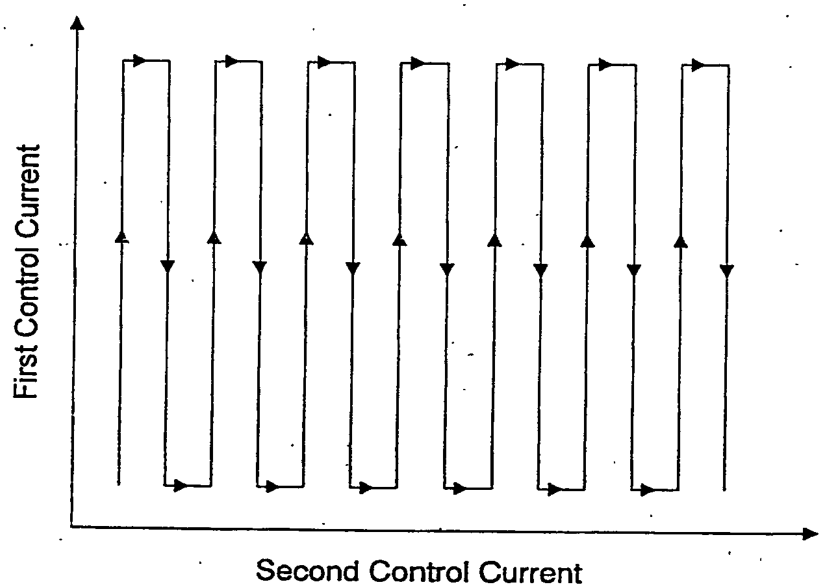

Figure 2

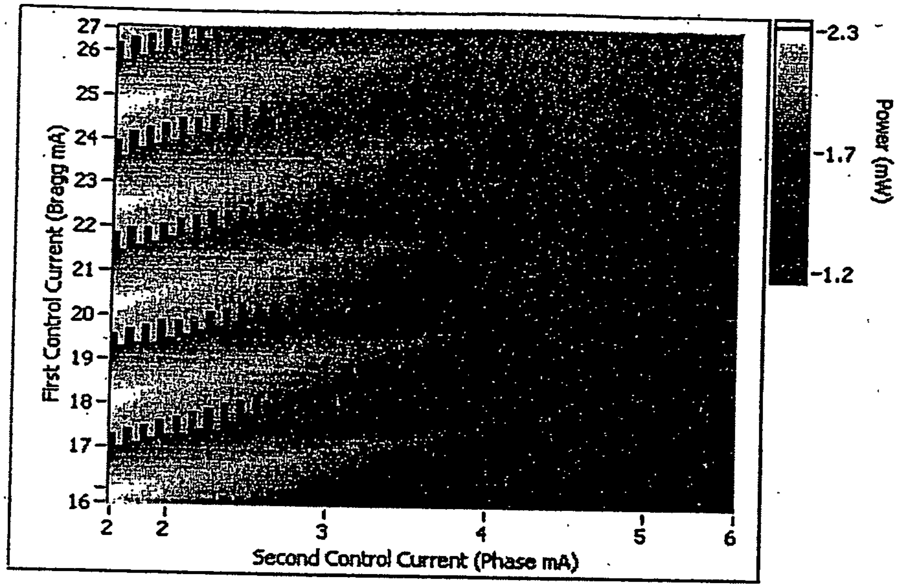

Figure 3

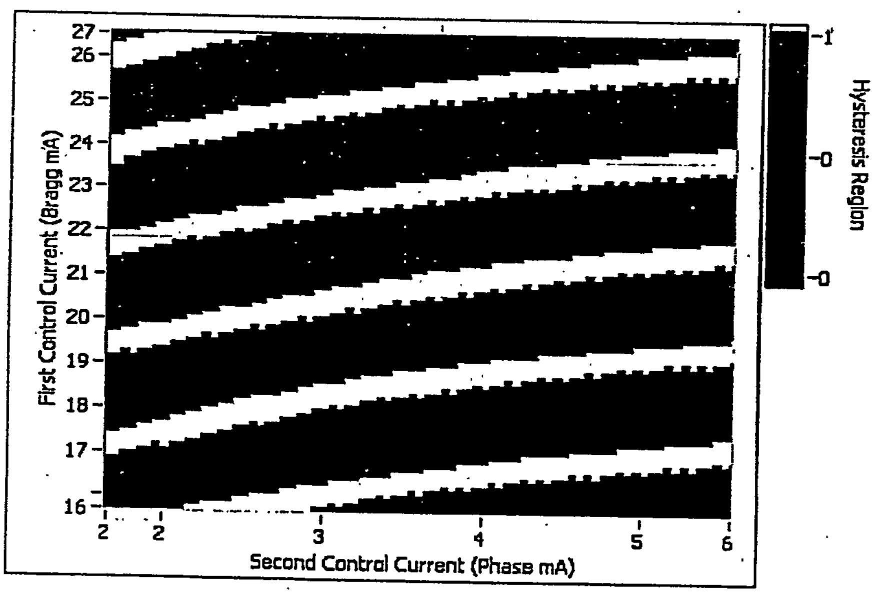

Figure 4

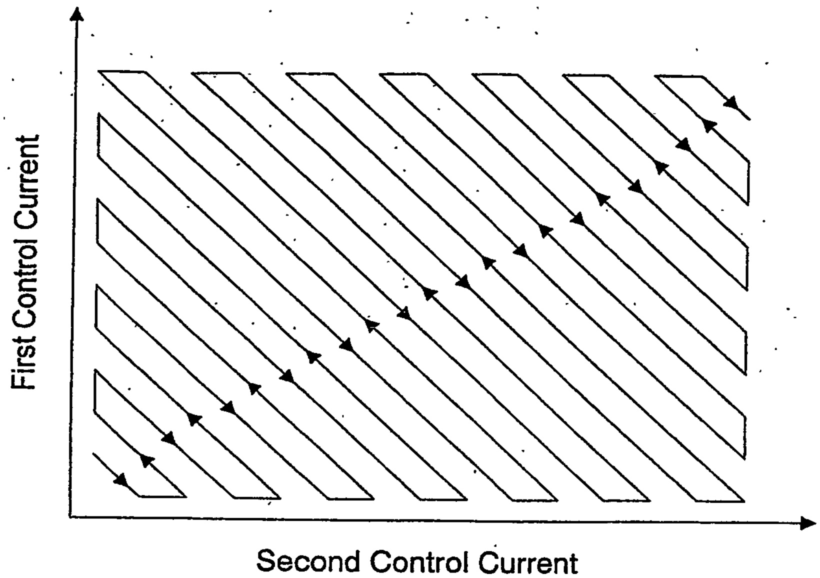

Figure 5